Stormwater Drainage Technical Requirements

Warsaw, Indiana

Prepared for:

The City of Warsaw

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Executive Summary

The City of Warsaw, as well as many other communities, has begun to experience an increase in drainage problems related to development. As land is developed, rainwater that previously soaked into the ground, now runs off into swales and streams. If these swales and streams cannot handle this additional water, flooding results. The guidelines presented in these requirements give the designer a method of quantifying the additional runoff created by development and methods of detaining the runoff to prevent flooding. These requirements also establish standards for the design of storm sewer systems, detention basins and open channels.

The following is a brief summary of the purpose of each section of the requirements and how they might be used.

Section 1 and 2 explain the background and purpose of these requirements and give definitions of some key terms used in this document.

Section 3 is the primary point of the document. This section defines the stormwater policy and specifies the amount of runoff that can be released. The runoff released after development during a 100 year storm (a storm of such intensity that, statistically, it will only occur once every 100 years) cannot exceed the amount of runoff that occurred during a 10 year storm before development. The calculations required to determine compliance with this policy are found in Sections 6 and 10. The Rational Method, discussed in Section 6, is used to determine the runoff from a 10 year storm for predeveloped conditions. Section 10 describes a method, based on the Rational Method, for computing the amount of storage that is needed to temporarily detain the excess water from a 100 year storm.

Section 4 describes when a permit is needed from the Department of Natural Resources for construction in a floodway.

Section 5 describes the information required on the plans for the primary and secondary approval submission. This information is needed by the Plan Commission to make certain that the design of the plans meets the guidelines set forth by these requirements.

Section 6 explains the Rational Method and how it is used to determine runoff quantities for drainage areas less than 200 acres. A worksheet is provided in this section to summarize the calculations required to design a storm sewer based on the Rational Method and Manning's Equation. Other methods for determining runoff quantities for areas larger than 200 acres are listed. These methods are too complex for the scope of this document but can be easily found in other hydraulic and hydrology reference texts.

Section 7 describes the amount of rainfall that various components of a drainage facility must be able to accommodate. For instance, inlets, catch basins, street gutters, sewers and swales must be designed to accommodate a 10 year storm.

Section 8 contains design standards for storm sewer systems. This section addresses issues such as minimum pipe sizes, minimum pipe slopes, maximum manhole spacing and construction requirements.

Section 9 addresses the similar issues for Open Channels such as minimum and maximum side slopes, channels linings, minimum cross sections and construction requirements.

Section 10 describes a method for designing and sizing stormwater detention facilities based on the Rational Method. A blank worksheet for summarizing the calculations required for this method and a completed example of this worksheet are included in this section. Design requirements for wet and dry detention basins and other types of storage are also included. A less involved alternative to the Rational Method is given for parcels less than two acres.

Section 11 contains requirements for "As-Built" plans.

Section 12 describes the necessary steps to change Plans that have received final approval.

Section 13 describes miscellaneous requirements for sump pumps, down spouts, footing drains and basement floor drains.

Section 14 removes liability from the City for any flood damage that might occur from facilities designed according to these requirements.

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Section 1. Purpose

It is recognized that smaller streams and drainage channels serving the City of Warsaw may not have sufficient capacity to receive and convey the additional storm water runoff, created by development.

Therefore, it shall be the policy of Warsaw City Plan Commission that the storage and controlled release of storm water runoff shall be required of all new development, any redevelopment and other new construction in the City of Warsaw. The release rate of storm water from developed lands shall not exceed the release rate from the land area in its present land use.

Because topography and the availability and adequacy of outlets for storm runoff vary with almost every site, the requirements for storm drainage tend to be an individual matter for any project. It is recommended that each proposed project be discussed with the Plan Commission or the appointed Plan Director at the earliest practical time in the planning stage.

In addition to these requirements, compliance with the requirements set forth in other applicable ordinances with respect to submission and approval of preliminary and final subdivision plats, improvement plans, building and zoning permits, construction inspections, appeals, and similar matters, and compliance with applicable State of Indiana statutes and regulations shall be required.

Section 2. Definitions

For the purpose of these requirements, the following definitions shall apply:

2.1 Plan Commission - The Warsaw City Plan Commission.

2.2 Capacity of a Storm Drainage Facility - The maximum flow that can be conveyed or stored by a storm drainage facility without causing damage to public or private property.

2.3 Channel - A natural or artificial watercourse which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. It has a defined bed and banks which serve to confine the water.

2.4 Compensatory Storage - An artificial volume of storage within a floodplain used to balance the loss of natural flood storage capacity when artificial fill or structures are placed within the floodplain.

2.5 Contiguous - Adjoining or in actual contact with.

2.6 Culvert - A closed conduit used for the passage of surface drainage water under a roadway, railroad, canal, or other impediment.

2.7 Detention Basin - A facility constructed or modified to restrict the flow of storm water to a prescribed maximum rate, and to detain concurrently the excess waters that accumulate behind the outlet.

2.8 Detention Storage - The temporary detaining or storage of storm water in storage basins, on rooftops, in streets, parking lots, school yards, parks, open spaces, or other areas under predetermined and controlled conditions, with the rate of drainage therefrom regulated by appropriately installed devices.

2.9 Drainage Area - The area from which water is carried off by a drainage system; a watershed or catchment area.

2.10 Drop Manhole - A manhole having a vertical drop pipe connecting the inlet pipe to the outlet pipe. The vertical drop pipe shall be located immediately outside the manhole.

2.11 Dry Bottom Detention Basin - A basin designed to be completely dewatered after having provided its planned detention of runoff during a storm event.

2.12 Duration - The time period of a rainfall event.

2.13 Erosion - Wearing away of the land by running water, waves, temperature changes, ice or wind.

2.14 Flood Elevation - The elevation at all locations delineating the maximum level of high waters for a flood of given return period and rainfall duration.

2.15 Flood or Flood Waters - The water of any watercourse which is above the banks of the watercourse. It also means the water of any lake which is above and outside the banks thereof.

2.16 Flood Hazard Area - Any flood plain, floodway, floodway fringe, or any combination thereof which is subject to inundation by the regulatory flood; or any flood plain as delineated by Zone A on a Flood Hazard Boundary Map.

2.17 Flood Plain - The area adjoining the river or stream which has been or may hereafter be covered by flood waters.

2.18 Flood Protection Grade - The elevation of the lowest floor of a building. If a basement is included, the basement floor is considered the lowest floor.

2.19 Floodway - See Regulatory Floodway.

2.20 Floodway Fringe - That portion of the flood plain lying outside the floodway, which is inundated by the regulatory flood.

2.21 Footing Drain - A drain pipe installed around the exterior of a basement wall foundation to relieve water pressure caused by high groundwater elevation.

2.22 Grade - The inclination or slope of a channel, canal, conduit, etc., or natural ground surface usually expressed in terms of the percentage the vertical rise (or fall) bears to the corresponding horizontal distance.

2.23 Impact Areas - Areas defined and mapped by the Plan Commission which are unlikely to be easily drained because of one or more factors including but not limited to any of the following soil type, topography, land where there is not adequate outlet, a floodway or floodplain, land within 75 feet of each bank of any regulated drain or within 75 feet from the centerline of any regulated tile ditch.

2.24 Impervious - A term applied to material through which water cannot pass, or through which water passes with difficulty.

2.25 Inlet - An opening into a storm sewer system for the entrance of surface storm water runoff, more completely described as a storm sewer inlet.

2.26 Junction Chamber - A converging section of conduit, usually large enough for a person to enter, used to facilitate the flow from one or more conduits into a main conduit.

2.27 Lateral Storm Sewer - A sewer that has inlets connected to it but has no other storm sewer connected.

2.28 Manhole - Storm sewer structure through which a person may enter to gain access to an underground storm sewer or enclosed structure.

2.29 Major Drainage Systems - Drainage systems carrying runoff from an area of one or more square miles.

2.30 Minor Drainage Systems - Drainage systems having area of less than one square mile.

2.31 Off-Site - Everything not in site.

2.32 On-Site - Located within the controlled area where runoff originates.

2.33 Outfall - The point or location where storm runoff discharges from a sewer or drain. Also applies to the outfall sewer or channel which carries the storm runoff to the point of outfall.

2.34 Peak Flow - The maximum rate of flow of water at a given point in a channel or conduit resulting from a particular storm or flood.

2.35 Radius of Curvature - Length of radius of a circle used to define a curve.

2.36 Rainfall Intensity - The cumulative depth of rainfall occurring over a given duration, normally expressed in inches per hour.

2.37 Reach - Any length of river, channel or storm sewer.

2.38 Regulated Area - All of the incorporated land under the jurisdiction of the City of Warsaw Plan Commission.

2.39 Regulatory Flood - That flood having a peak discharge which can be equaled or exceeded on the average of once in a one hundred (100) year period, as calculated by a method and procedure which is acceptable to the Plan Commission. If a permit from the National Resources Commission for construction in the floodway is required (see Section VI), then the regulatory flood peak discharge should be calculated by a method acceptable to the Board and the Department of Natural Resources. This regulatory flood is equivalent to a flood having a probability of occurrence of one percent (1%) in any given year.

2.40 Regulatory Floodway - The channel of a river or stream and those portions of the floodplains adjoining the channel which are reasonably required to carry and discharge the peak flow of the regulatory flood of any river or stream.

2.41 Retention - Indefinitely storing or holding storm water in a basin without a positive outlet.

2.42 Release Rate - The amount of storm water released from a storm water control facility per unit of time.

2.43 Return Period - The average interval of time within which a given rainfall event will be equalled or exceeded once. A flood having a return period of 100 years has a one percent probability of being equalled or exceeded in any one year.\

2.44 Riprap - Randomly placed stone of various sizes used to protect the banks of channels and streams from erosion.

2.45 Runoff Coefficient - A decimal fraction relating the amount of rain which appears as runoff and reaches the storm drainage system to the total amount of rain falling. A coefficient of 0.5 implies that 50 percent of the rain falling on a given surface appears as storm water runoff.

2.46 Sediment - Material of soil and rock origin, transported, carried or deposited by water.

2.47 Siphon - A closed conduit or portion of which lies above the hydraulic grade line, resulting in a pressure less than atmospheric and requiring a vacuum within the conduit to start flow. A siphon utilizes atmospheric pressure to effect or increase the flow of water through a conduit. An inverted siphon is used to carry storm water flow under an obstruction such as a sanitary sewer.

2.48 Spillway - A waterway in or about a hydraulic structure, for the escape of excess water.

2.49 Stilling Basin - A basin used to slow water down or dissipate its energy.

2.50 Storage Duration - The length of time that water may be stored in any storm water control facility, computed from the time water first begins to be stored.

2.51 Storm Sewer - A closed conduit for conveying collected storm water.

2.52 Storm Water Drainage System - All means, natural or man-made, used for conducting storm water to, through or from a drainage area to any of the following: conduits and appurtenant features, canals, channels, ditches, streams, culverts, streets and pumping stations.

2.53 Storm Water Runoff - The water derived from rains falling within a tributary basin, flowing over the surface of the ground or collected in channels or conduits.

2.54 Tributary - Contributing storm water from upstream land areas.

2.55 Urbanization - The development, change or improvement of any parcel of land consisting of one or more lots for residential, commercial, industrial, institutional, recreational or public utility purposes.

2.56 Watercourse - Any river, stream, creek, brook, branch, natural or man-made drainage way in or into which storm water runoff or floodwaters flow either regularly or intermittently.

2.57 Watershed - See Drainage Area.

2.58 Wet Bottom Detention Basin - (Retention Basin) - A basin designed to retain a permanent pool of water after having provided its planned detention of runoff during a storm event.

Section 3. Storm Water Control Policy

It is recognized that the smaller streams and drainage channels serving the City of Warsaw may not have sufficient capacity to receive and convey storm water runoff resulting from continued urbanization. Accordingly, the storage and controlled release of excess storm water runoff shall be required for any development, redevelopment and new construction located within the City of Warsaw.

Possible exceptions to the requirement are described in Section 1.11 of the Development Plan Ordinance. The Plan Commission or the appointed Plan Director after thorough investigation and evaluation, may waive the requirement of controlled runoff for minor developments. Minor developments would include individual single and double family residential lots.

The release rate of storm water from development, redevelopment, and new construction may not exceed the storm water runoff from the land area in its present state of development. The developer must submit to the Plan Commission detailed computations of runoff before and after development, redevelopment or new construction which demonstrate that runoff will not be increased.

These computations must show that the peak runoff rate after development for the 100 year return period storm of critical duration must not exceed the 10 year return period pre-development peak runoff rate. The critical duration storm is that storm duration which requires the greatest detention storage.

Computations for areas up to and including 200 acres may be based on the Rational Method; typical runoff coefficients are listed herein. For areas larger than 200 acres, hydrograph techniques and/or computer drainage modeling methods may be used. Hydrograph techniques and computer modeling methods used to determine storm water runoff shall be proven methods, subject to approval of the Plan Commission or appointed Plan Director.

Section 4. Permits for Construction in the Floodway

Chapter 318 of the Acts of 1945, as amended, Sections 17 and 19, require the Department of Natural Resources' approval of any construction in a floodway, and of any works for flood control. This includes bridges, dams, levees, dikes, floodwalls, wharves, piers, dolphins, booms, weirs, bulkheads, jetties, groins, excavations, fills or deposits of any kind, utility lines, or any other building, structure, or obstruction. Also, any ditch work (new construction, deepening or modification) within one half mile of a public freshwater lake of 10 acres or more in area.

The approval of the Department of Natural Resources (DNR), in writing, must be obtained before beginning construction. Applications for approval should be submitted to:

Department of Natural Resources
Division of Water
Room W264 Indiana Government Center South
402 West Washington Street
Indianapolis, Indiana 46204

All applications should be made on the standard application form provided by the DNR and should be accompanied by plans, profiles, specifications, and other data necessary for the DNR to determine the effect of the proposed construction upon the floodway and on flood control in the state.

Application made to and approval granted by the DNR does not in any way relieve the owner of the necessity of securing easements or other property rights, and permits and/or approvals from affective property owners and local, state, and federal agencies.

The engineering staff of the Division of Water is available to discuss and offer suggestions regarding requirements in the design of structures in floodways. High water marks have been set on many of the streams in the state, and information is available from the Division of Water on actual and/or potential flooding. Information regarding bench marks set to Mean Sea Level Datum, General Adjustment of 1929, is available from the Division of Water, Surveying and Mapping Section.

A fee is charged by the DNR approvals under the Flood Control Act. Unless stated otherwise in the approval, construction is considered to be a permanent development, and no renewals of the approval are necessary, except in the cases where temporary approvals are granted for temporary construction. The right is reserved to require additional data where necessary.

Section 5. Information Requirements

The following information and data provided by an Indiana licensed professional engineer, architect or land surveyor engaged in storm drainage design shall be submitted to the Plan Commission at the time of application for a building permit for any development, redevelopment or new construction on real estate which meets the criteria of project size and type that is regulated under these requirements.

5.1 Topographic and Soils Maps

A soils map of the proposed development indicating soils names and their hydrologic classification must be provided when Soil Conservation Service (SCS) hydrologic methods are used. In addition, a topographic map of the land to be subdivided and such adjoining land whose topography may affect the layout or drainage of the development must be provided. The contour intervals shall be one foot when slopes are less than four percent and shall be two feet when the slope exceeds four percent. On this map, the following shall be shown:

A. The location of streams and other flood water runoff channels, the extent of the floodplains at the established 100 year flood elevation where available (regulatory floodway), and the limits of the floodway, all properly identified.

B. The normal shoreline of lakes, ponds, swamps and detention basins, their floodplains, and lines of inflow and outflow if any.

C. The location of regulated drains, farm drains, inlets and outfalls, if any of record.

D. Storm, sanitary and combined sewers and outfalls, if any of record.

E. Septic tank systems and outlets, if any of record.

F. Seeps, springs, flowing and other wells, that are visible or of record.

5.2 Primary Approval Drainage Plans

A comprehensive plan, in preliminary form (or in combined preliminary and final form), designed to handle safely the storm water runoff and to detain the increased storm water runoff must be provided. The plan shall provide or be accompanied by maps or other descriptive materials indicating the feasibility of the drainage plan and showing the following:

A. The extent and area of each watershed affecting the design of detention facilities as shown on USGS Quadrangle Maps or other more detailed maps as required by the Plan Commission.

B. The preliminary layout and design of proposed storm sewers, the outfall and outlet locations and approximate elevations, the receiving stream or channel and its 100 year return period water elevation.

C. The location and design of the proposed street system, especially including depressed pavements used to convey or temporarily store overflow from the heavier rainstorms, and the outlets for such overflow.

D. The locations, cross sections and profiles of existing streams and floodplains to be maintained, and new channels to be constructed.

E. The materials, elevations, waterway openings, and the basis for design of proposed culverts and bridges.

F. Existing ponds and basins to be maintained, enlarged, or otherwise altered and new ponds or basins to be built and the basis of their design.

G. The estimated depth and amount of storage required in the new ponds or basins.

H. The estimated location and percentage of impervious surfaces existing and expected to be constructed when the development is completed.

I. Any interim plan which is to be incorporated into the development pending completion of the development and the final drainage plan.

5.3 Valley Cross Section

One or more typical cross sections must be provided showing all existing and proposed channels or other open drainage facilities carried to a point above the 100 year high water elevation; showing the elevation of the existing land and the proposed changes thereto, together with the high water elevations expected from the 100 year storm under the controlled conditions called for by these requirements; and showing the relationship of structures, streets, and other facilities.

5.4 Site Plan

A plan drawn to scale showing dimensions of the site with existing and proposed storm drainage facilities must be provided.

5.5 Secondary Approval Drainage Plans

After primary approval of the drainage plans has been granted by the Plan Director, final drainage plans shall be submitted to the Plan Commission for Secondary Approval. The final plans shall provide or be accompanied by calculations, maps and/or other descriptive material showing the following:

A. The extent and area of each watershed tributary to the drainage channels in the development.

B. The street storm sewers and other storm drains to be built, the basis of their design, outfall and outlet locations and elevations, the receiving stream or channel and its high water elevation, and the functioning of the drains during high water conditions.

C. The parts of the proposed street system where pavements are planned to be depressed sufficiently to convey or temporarily store overflow from storm sewers and over the curb runoff resulting from the heavier rainstorm and the outlets for such overflow.

D. Existing streams and floodplains to be maintained, and new channels to be constructed, their locations, cross sections and profiles.

E. Proposed culverts and bridges to be built, their materials, elevations, waterway openings and basis of their design.

F. Existing detention basins and ponds to be maintained, enlarged, or otherwise altered and new basins or ponds to be built and the basis of their design.

G. The estimated location and percentage of impervious surfaces existing and expected to be constructed when the development is completed.

H. The slope, type and size of all sewers and other waterways.

I. For all detention basins, a plot or tabulation of storage volumes with corresponding water surface elevations and a plot or tabulations of the basin outflow rates for those water surface elevations.

5.6 Submittal and Consideration of Plans

Preliminary and Final Drainage Plans shall be submitted as part of the Plans for Primary and Secondary Approval as described in the Development Plan Ordinance.

Section 6. Determination of Runoff Quantities

Runoff quantities shall be computed for the area of the parcel under development plus the area of the watershed flowing into the parcel under development. The quantity of runoff which is generated as the result of a given rainfall intensity may be calculated as follows:

6.1 Rational Method for Areas 200 Acres or Less

For areas up to and including 200 acres, the Rational Method may be used. In the Rational Method, the peak rate of runoff, Q, in cubic feet per second is computed as:

$$Q = CIA \qquad (6.1.1)$$

where: C = runoff coefficient, representing the characteristics of the drainage area and defined as the ratio of runoff to rainfall.

I = average intensity of rainfall in inches per hour for a duration equal to the time of concentration (t_c) for a selected rainfall frequency.

A = tributary drainage area in acres.

Guidance to selection of the runoff coefficient "C" is provided in Tables 1,2 and 3 which show values for different types of surface and local soil characteristics. The composite "C" value used for a given drainage area with various surface types shall be the weighted average value for the total area calculated from a breakdown of individual areas having different surface types.

In the instance of undeveloped land situated in an upstream area, a coefficient or coefficients shall be used for this area in its present or existing state of development.

Rainfall intensity shall be determined from the rainfall frequency curves shown in Figure 1 or from Equation 6.1.2.

$$i = \frac{cT_r^{\alpha}}{(t+d)^{\beta}} \qquad (6.1.2)$$

i = rainfall intensity (inches/hour)
T_r = recurrence Interval (years)
t = storm duration (hours)
c, d, α, β = regional coefficients determined by evaluation of rainfall intensity - duration - frequency curves. These coefficients have been calculated for several major cities by Purdue et. al., 1992 and are shown in Table 4. Coefficients for Fort Wayne are recommended for the Warsaw area.

The time of concentration (t_c) to be used shall be the sum of the inlet time and flow time in the drainage facility from the most remote part of the drainage area to the point under consideration. The flow time in the storm sewers may be estimated by the distance in feet divided by velocity of flow in feet per second. The velocity shall be determined by Manning's Formula.

Inlet time is the combined time required for the runoff to reach the inlet of the storm sewer. It includes overland flow time and flow time through established surface drainage channels such as swales, ditches and sheet flow across such areas as lawns, fields, and other graded surfaces.

The Kirpich Equation (Equation 6.1.3) may be used to compute these components of the time of concentration.

$$t_c = K\left[\frac{11.9 \times L^3}{H}\right]^{.385} \qquad (6.1.3)$$

t_c = Time of Concentration (hours)
L = Length traveled by Water (miles)
H = Fall from Point of Calculation (feet)
K = 1 for natural basins with well defined channels, for overland flow on bare earth and for mowed grass roadside channels.
K = 2 for overland flow on grassed surfaces
K = 0.2 for concrete channels
K = 0.4 for overland flow on concrete or asphalt surfaces

A nomograph derived from this equation is included in Figure 2. Other proven methods subject to the approval of the Plan Commission or appointed Plan Director may also be used to compute time of concentration.

A worksheet summarizing the calculations for designing a storm sewer system with the Rational Method can be found in Figure 3. An explanation of the information required in each column of the worksheet can be found in Table 5. This worksheet also uses Manning's Equation (Equation 8.1.1) which is explained in Section 8.1. Standards for designing a storm sewer are found in Section 8.

Table 1 - Rural Runoff Coefficients[1]

Vegetation and Topography	Soil Texture: Open Sandy Loam	Clay Silt Loam	Tight Clay
Woodland			
Flat 0-5% slope	0.10	0.30	0.40
Rolling 5-10% slope	0.25	0.35	0.50
Hilly 10-30% slope	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Hilly	0.22	0.42	0.60
Cultivated			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70
Hilly	0.52	0.72	0.82

[1]Schwab, G.O., Frevert, R.K., Barnes, K.K., Edminster, T.W., Elementary Soil and Water Engineering, John Wiley & Sons, Inc., New York, 1971, p.76.

Table 2 - Urban Runoff Coefficients for the Rational Method[1]

Description of Area	Runoff Coefficients
Business	
Downtown	0.70 to 0.95
Neighborhood	0.50 to 0.70
Residential	
Single-family	0.30 to 0.50
Multi-units, detached	0.40 to 0.60
Multi-units, attached	0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment	0.50 to 0.70
Industrial	
Light	0.50 to 0.80
Heavy	0.60 to 0.90
Parks, cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad yard	0.20 to 0.35
Unimproved	0.10 to 0.30

Table 3 - Values Used to Determine a Composite Runoff Coefficient for an Urban Area[1]

Character of Surface	Runoff Coefficients
Pavement	
Asphalt and Concrete	0.70 to 0.95
Brick	0.70 to 0.85
Roofs	0.75 to 0.95
Lawns, sandy soil	
Flat, 2 percent	0.05 to 0.10
Average, 2 to 7 percent	0.10 to 0.15
Steep, 7 percent	0.15 to 0.20
Lawns, heavy soil	
Flat, 2 percent	0.13 to 0.17
Average, 2 to 7 percent	0.18 to 0.22
Steep, 7 percent	0.25 to 0.35
Water Impoundment	1.00

[1]American Society of Civil Engineers, "Design and Construction of Urban Stormwater Management Systems", ASCE Manuals and Reports on Engineering Practice, No. 77, (WEF Manual of Practice FD-20), American Society of Civil Engineers, 1992.

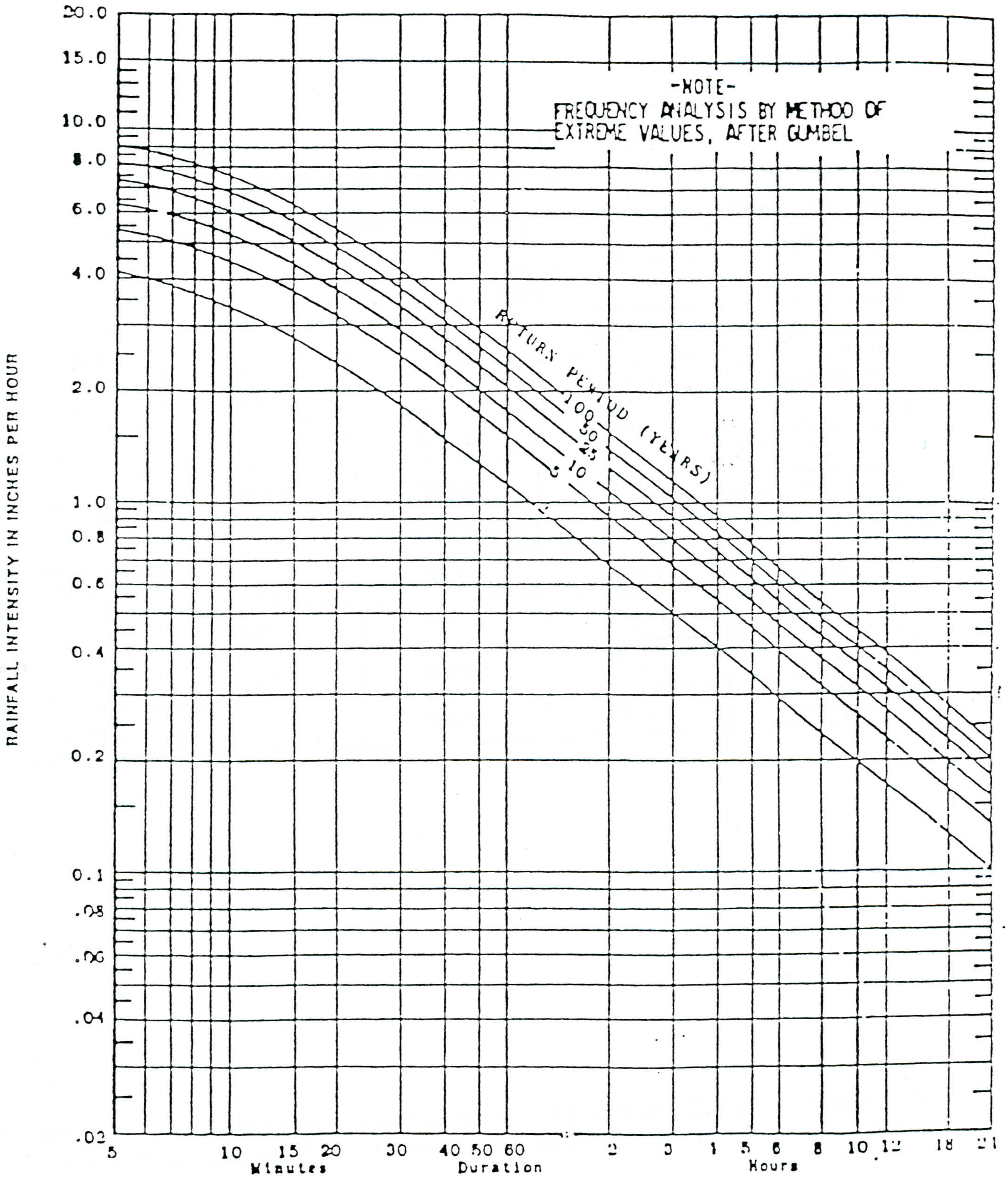

Figure 1 Rainfall Intensity-Duration-Frequency Curves

Fort Wayne, Indiana 1911 - 1951

(U.S. Department of Commerce - Weather Bureau - Cooperative Studies Section)

Table 4 - Regional Coefficients for the IDF Equation[1]

Station	c	α	d	β
0.083 hour $< t \leq 1$ hour				
Indianapolis	2.1048	0.1733	0.470	1.1289
South Bend	1.7204	0.1753	0.485	1.6806
Evansville	1.9533	0.1747	0.522	1.6408
Fort Wayne	2.0030	0.1655	0.516	1.4643
1 hour $< t <$ 36 hour				
Indianapolis	1.5899	0.2271	0.725	0.8797
South Bend	1.2799	0.1872	0.258	0.8252
Evansville	1.3411	0.2166	0.300	0.8154
Fort Wayne	1.4381	0.1878	0.525	0.8616

[1]Purdue, A.M., Jeong, G.D., and Rao, A.R., "Statistical Characteristics of Short Time Increment Rainfall", Tech. Report CE-EHE-92-09, Environmental and Hydraulic Engineering, Purdue University, 1992.

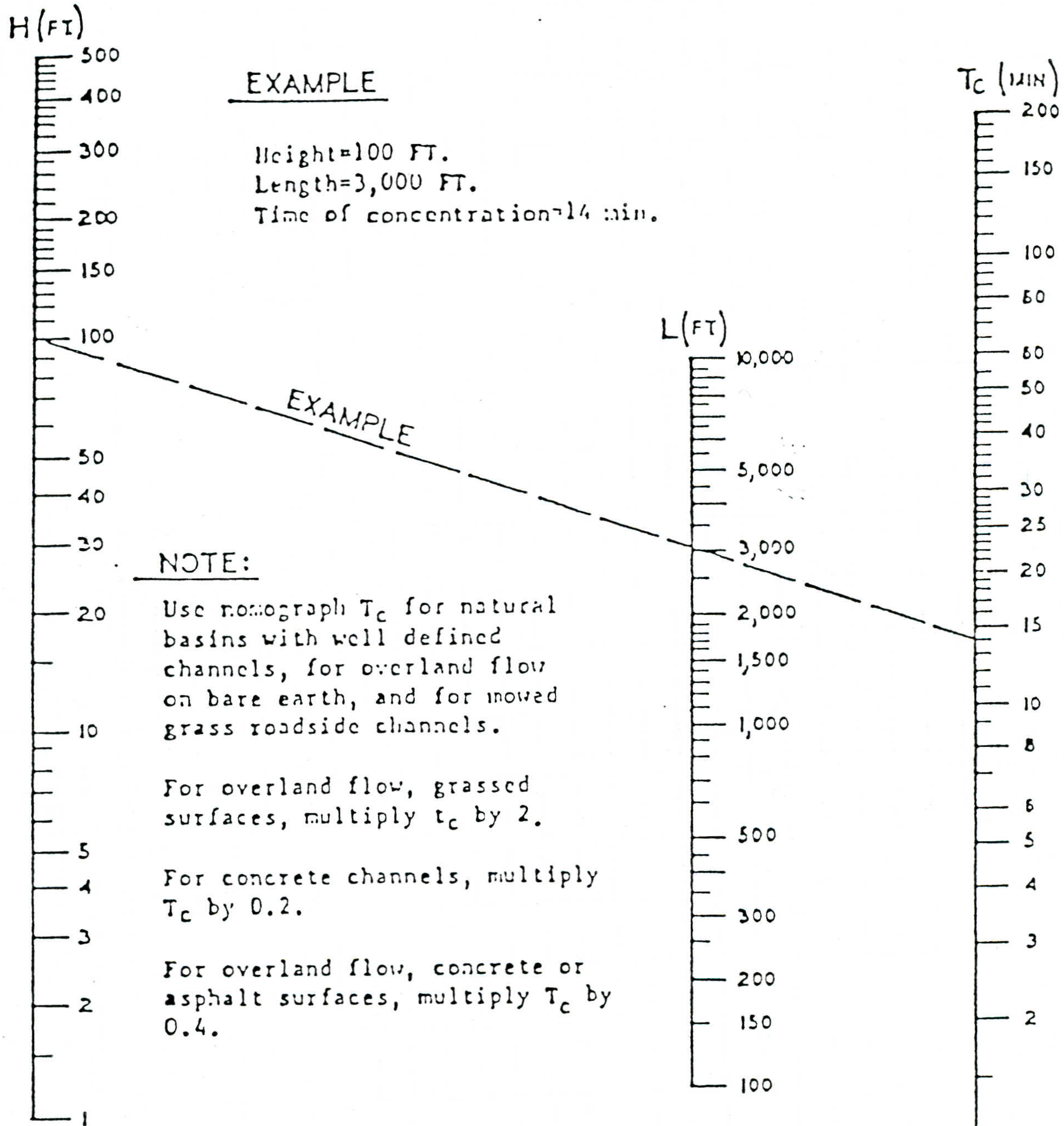

Figure 2. Nomograph for Determining Time of Concentration (developed from the Kirpich Equation). (1)

(1) From Ordinance 81-16, Tippecanoe County, Indiana, A General Ordinance Establishing Storm Drainage and Sediment Control, November 1981.

Figure 5. Storm Sewer Design Sheet - Rational Method

PROJECT________________________________ Date______________ Sheet ________ of ________

ENGINEER____________________________ Design Storm______________ Manning's n__________

Line No.	Upstr. MH	Dnstr. MH	Length	Cj	Aj	Cj x Aj	Sum Cj x Aj	tj	t cum	i	Q	Pipe Diam	Pipe Slope	Pipe Cap.	Vel.	Travel Time	Rim Elev. Upstr.	Rim Elev. Dnstr.	Invert Elev. Upstr.	Invert Elev. Dnstr.	Pipe Cover Upstr.	Pipe Cover Dnstr.
			(ft)		(Acres)			(min)	(min)	(in/hr)	(cfs)	(in)	(%)	(cfs)	(ft/s)	(min)					(ft)	(ft)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

Table 5 - Explanation of Column Headings for Storm Sewer Design Worksheet.

Column 1	Identification number of the particular structure.
Column 2	Identification number of the manhole at the upstream end of the pipe.
Column 3	Identification number of the manhole at the downstream end of the pipe.
Column 4	Length of the pipe under consideration.
Column 5	Runoff coefficient of the subbasin. This may be a weighted composite based on the type of cover in the subbasin.
Column 6	Area of the subbasin, in acres, entering the pipe.
Column 7	Product of the runoff coefficient (Col. 5) and the subbasin area (Col. 6).
Column 8	Sum of the runoff coefficients and area products (Col. 7) contributing to the pipe under consideration.
Column 9	Time to inlet in minutes
Column 10	Maximum inlet time and total travel time for the water from the most distant subbasin to contribute to this pipe (the longest travel time when all are considered).
Column 11	Rainfall intensity for the storm design frequency and storm duration equal to the time of concentration (Column 10).
Column 12	Peak flow rate for the reach under consideration, $Q = i\sum CA$ = Col. 11 x Col. 9.
Column 13	Pipe Diameter in inches
Column 14	Pipe slope between structures.
Column 15	Full flow capacity of the pipe with diameter selected in Column 13 and slope in Column 14, determined using Manning's Equation.
Column 16	Full pipe velocity found by $V = Q/A$.
Column 17	Travel time in the reach found by $T = L/60V$.
Column 18	Rim elevation of upstream manhole.
Column 19	Rim elevation of downstream manhole.
Column 20	Invert elevations of the pipe at the upstream structures.
Column 21	Invert elevations of the pipe at the downstream structures.
Column 22	Pipe cover at the upstream end Col. 18 - Col. 20 - Col. 13

Adapted from HERPICC Stormwater Drainage Manual - Revised July 1994

6.2 Other Methods for Areas Greater Than 200 Acres

The runoff rate for areas in excess of 200 acres shall be determined by methods described in Section 10.6.

Section 7. Accommodation of Runoff

Various parts of a drainage facility must accommodate runoff water as follows:

7.1 Minor Systems

The minor drainage system such as inlets, catch basins, street gutters, swales, sewers and small channels which collect storm water must accommodate peak runoff from a 10-year return period storm. Rainfall duration shall be equal to the time of concentration. A first quartile storm distribution shall be used for computer modeling. These minimum requirements must be satisfied:

A. The allowable spread of water on Collector Streets is limited to maintaining two clear 10 foot moving lanes of traffic. One lane is to be maintained on Local Roads.

B. Open channels carrying peak flows greater than 30 cubic feet per second shall be capable of accommodating peak runoff for a 50-year return period storm within the drainage easement.

C. Culverts shall be capable of accommodating peak runoff from a 100-year return period storm when crossing under a road which is part of the Indiana Department of Transportation rural functional classification system and are classified as principal or minor arterial, major or minor collector roads. (See Indiana Department of Transportation Hydraulic Guidelines November 1993)

7.2 Major Systems

Major drainage systems are defined in Section II, subsection CC and shall be designed in accordance with Indiana Department of Natural Resources Standards as described in Section IV.

Section 8. Storm Sewer Design Standards

All storm sewers, whether private or public, and whether constructed on private or public property shall conform to the design standards and other requirements contained herein.

8.1 Manning's Equation

The hydraulic capacity of storm sewers shall be determined using Manning's Equations:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \qquad (8.1.1)$$

$$Q = VA = \frac{1.486}{n} AR^{2/3} S^{1/2} \qquad (8.1.2)$$

Q = volumetric flow rate in cubic feet per second
V = mean velocity of flow in feet per second
A = cross sectional area of flow
R = the hydraulic radius in feet
S = the slope of the energy grade line in feet per foot
n = roughness coefficient

The hydraulic radius, R, is defined as the cross sectional area of flow divided by the wetted flow surface or wetted perimeter. Typical "n" values and maximum permissible velocities for storm sewer materials are listed in Table 6. Roughness coefficient "n" values for other sewer materials can be found in standard hydraulics texts and references.

8.2 Minimum Size

The minimum size of all storm sewers shall be 12 inches. Rate of release for detention storage shall be controlled by an orifice plate or other devices, subject to the approval of the Plan Commission, where the 12 inch pipe will not limit rate of release as required.

8.3 Grade

Sewer grade shall be such that, in general, a minimum of two feet of cover is maintained over the top of the pipe. Pipe cover less than the minimum may be used only upon approval of the Plan Commission. Uniform slopes shall be maintained between inlets, manholes and inlets to manholes. Final grade shall be set with full consideration of the capacity required, sedimentation problems and other design parameters.

The minimum allowable grade shall produce velocities not less than two and one-half (2.5) feet per second when the sewer is flowing full. The maximum allowable grade shall produce velocities not greater than 15 feet per second when the sewer is flowing full.

Table 6 - Typical Values of Manning's Roughness Coefficient, n

Material	Manning's n	Desirable Maximum Velocities
Closed Conduits		
Concrete	0.013	15 f.p.s.
Vitrified Clay	0.013	15 f.p.s.
Brick	0.015	15 f.p.s.
Cast Iron	0.013	15 f.p.s.
Circular Corrugated Metal Pipe, Annular Corrugations,2 2/3 x 1/2 in.		
Unpaved	0.024	7 f.p.s.
25% Paved	0.021	7 f.p.s.
50% Paved	0.018	7 f.p.s.
100% Paved	0.013	7 f.p.s.
Circular Corrugated Metal Pipe, Helical, 2 2/3 x 1.2 in. Unpaved Corrugations		
12"	0.011	
18"	0.013	
24"	0.015	
36"	0.018	
48"	0.020	
60" or larger	0.021	
Corrugated Polyethylene Smooth Interior Pipe	0.012	15 f.p.s.
Concrete Culverts	0.013	
Open Channels		
Concrete, Trowel Finish	0.013	
Concrete, Broom or Float Finish	0.015	
Gunite	0.018	
Riprap Placed	0.030	
Riprap Dumped	0.035	
Gabion	0.028	
New Earth (Uniform, Sodded, Clay)	0.025	
Existing Earth (Fairly Uniform With Some Weeds)	0.030	
Dense Growth of Weeds	0.040	
Dense Weeds and Brush	0.040	
Swale With Grass	0.035	

From Marshall County Storm Drainage and Sediment Control Ordinance, Marshall County, Indiana, Ordinance 1993-7, 1993.

8.4 Alignment

Storm sewers shall be straight between manholes insofar as possible. Where long radius curves are necessary to conform to street layout, the minimum radius of curvature shall be no less than 100 feet for sewers 42 inches and larger in diameter. Deflection of pipe sections shall not exceed the maximum deflection recommended by the pipe manufacturer. The deflection shall be uniform and finished installation shall follow a smooth curve.

8.5 Manholes

Manholes shall be installed to provide access to continuous underground storm sewers for the purpose of inspection and maintenance. Manholes shall be provided at the following locations:

(1) Where two or more storm sewers converge.
(2) At the point of beginning or ending of a curve, and at the point of reverse curvature (PC, PT, PRC).
(3) Where pipe size changes.
(4) Where an abrupt change in alignment occurs.
(5) Where a change in grade occurs.
(6) At suitable intervals in straight sections of sewer.

The maximum distance between storm sewer manholes shall be as follows:

Size of Pipe (inches)	Maximum Distance feet
12 through 42	400
48 and larger	600

8.6 Inlets

Inlets or drainage structures shall be utilized to collect surface water through grated openings and convey it to storm sewers, channels or culverts. Inlet design and spacing shall be in accordance with Chapter 5 of the Highway Extension and Research Project for Indiana Counties and Cities (HERPICC) Storm Water Drainage Manual dated July 1994, or other approved design procedure. The inlet grate opening provided must be adequate to pass the design 10 year flow with 50% of the sag inlet area clogged. An overload channel from sag inlets to the overflow channel or basin shall be provided at sag inlets, so that the maximum depth of water that might pond in the street sag shall not exceed 7 inches.

8.7 Workmanship and Materials

A. Workmanship

The specifications for the construction of storm sewers shall not be less stringent than those set forth in the latest edition of the Indiana Department of Transportation's "Standard Specifications"; additionally, ductile iron pipe shall be laid in accordance with American Water Works Association (AWWA) C-600 and clay pipe shall be laid in accordance with American Society of Testing Materials (ASTM) C-12.

B. Materials

Storm sewer manholes and inlets shall be constructed of masonry, cast in place concrete or precast reinforced concrete. material and construction shall conform to Indiana Department of Transportation's "Standard Specifications", Section 720.

Pipe and fittings used in storm sewer construction shall be extra-strength clay pipe (ASTM C-700), ductile iron pipe (AWWA C-151), or concrete pipe (ASTM C-76). Other pipe and fittings not specified herein may be used only when specifically authorized by the Plan Commission. Pipe joints shall be flexible and watertight and shall conform to the requirements of Section 715.02 - Materials, of the latest edition of the Indiana Department of Transportation's "Standard Specifications".

C. Special Hydraulic Structures

Special hydraulic structures required to control the flow of water in storm runoff drainage systems include junction chambers, drop manholes, inverted siphons, stilling basins, and other special structures. The use of these structures shall be limited to those locations justified by prudent planning and by careful and thorough hydraulic engineering analysis.

Section 9. Open Channel Design Standards

All open channels, whether private of public, and whether constructed on private or public land, shall conform to the design standards and other design requirements contained herein.

9.1 Manning's Equation

The waterway for channels shall be determined using Manning's Equation.

$$Q = VA = \frac{1.486}{n} AR^{2/3} S^{1/2} \qquad (9.1.1)$$

Where: A = Waterway area of channel in square feet
Q = Discharge in cubic feet per second (cfs)
V = mean velocity of flow i feet per second
R = the hydraulic radius in feet
S = the slope of the energy grade line in feet per foot
n = roughness coefficient

9.2 Channel Cross Section and Grade

The required channel cross section and grade are determined by the design capacity, the material in which the channel is to be constructed, and the requirements for maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains, tributary ditches, or streams. The channel grade shall be such that the velocity in the channel is high enough to prevent siltation but low enough to prevent erosion. Velocities less than 1.5 feet per second should be avoided because siltation will take place and ultimately reduce the channel cross section. The maximum permissible velocities in vegetal-lined channels are shown in Table 7. Developments through which the channel is to be constructed must be considered in design of the channel section.

9.3 Side Slopes

Earthen channel side slopes shall be no steeper than 3 to 1. Flatter slopes may be required to prevent erosion and form ease of maintenance. Where channels will be lined, side slopes shall be no steeper than 1-1/2 to 1 with adequate provisions made for weep holes.

Side slopes steeper than 1-1/2 to 1 may be used for lined channels provided that the side lining and structural retaining wall are designed and constructed with provisions for live and dead load surcharge.

Table 7 - Maximum Permissible Velocities in Vegetal-Lined Channels[1]

Cover	Slope range (2 percent)	Permissible Velocity (1)	
		Erosion Resistant Soils (ft. per sec.)	Easily Eroded Soils (ft. per sec.)
Bermuda grass	0-5 5-10 over 10	8 7 6	6 5 4
Bahia Buffalo grass Kentucky bluegrass Smooth brome Blue grama	0-5 5-10 over 10	7 6 5	5 4 3
Grass mixtures Reed canary grass	(2) 0-5 5-10	5 4	4 3
Lespediza sericea Weeping love grass Yellow bluestem Redtop Alfalfa Red fescue	(3) 0-5	3.4	2.5
Common lespedeza (4) Sudangrass (4)	(5) 0-5	3.5	2.5

(1) Use velocities exceeding 5 feet per second only where good covers and proper maintenance can be obtained.

(2) Do not use on slopes steeper than 10 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.

(3) Do not use on slopes steeper than 5 percent except for vegetated side slopes in combination with stone, concrete, or highly resistant vegetative center section.

(4) Annuals - use on mild slopes or as temporary protection until permanent covers are established.

(5) Use on slopes steeper than 5 percent is not recommended.

[1]Soil Conservation Service, SCS-TP-61, Handbook of Channel Design for Soil & Water Conservation.

9.4 Channel Stability

A. Characteristics of a stable channel are:

1) It neither aggrades nor degrades beyond tolerable limits.
2) The channel banks do not erode to the extent that the channel cross section is changed appreciably.
3) Excessive sediment bars do not develop.
4) Excessive erosion does not occur around culverts, bridges or elsewhere.
5) Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.

B. Channel stability shall be determined for an aged condition and the velocity shall be based on the design flow or the bank full flow, whichever is greater, using "n" values for various channel linings as shown in Table 6. In no case is it necessary to check channel stability for discharges greater than that from a 100-year return period storm.

C. Channel stability must be checked for conditions immediately after construction. For this stability analysis, the velocity shall be calculated for the expected flow from a ten-year return period storm on the watershed, or the bank full flow, whichever is smaller. The "n" value for newly constructed channels in fine-grained soils and sands may be determined in accordance with the National Engineering Handbook 5, Supplement B, Soil Conservation Service and shall not exceed 0.025. The allowable velocity in the newly constructed channel may be increased by a maximum or 20 percent to reflect the effects of vegetation to be established under the following conditions:

1) The soil and site in which the channel is to be constructed are suitable for rapid establishment and support of erosion controlling vegetation.
2) Species of erosion controlling vegetation adapted to the area, and proven methods of establishment are shown.
3) The channel design includes detailed plans for establishment of vegetation on the channel side slopes.

9.5 Drainage of Waterways

Vegetated waterways that are subject to low flows of long duration or where wet conditions prevail shall be drained with a tile system or by other means such as paved gutters. Tile lines may outlet through a drop structure at the end of the waterway or through a standard tile outlet.

For grass-lined channels, intended to convey continuous trickle flows such as for detention pond outlets, an enclosed storm drain, subsurface tile with gravel envelope, rock rip-rap, or paved low flow channel will be required.

Concrete-lined channels shall be required by the Plan Commission or appointed Plan Director as deemed necessary to either control erosion and/or eliminate wetness within open stormwater conveyance channels.

To prevent chronic wetness in the in invert of open channels, subsurface tiles shall be installed a minimum of 1 1/2 feet in depth (from the tile invert), with a #8 gravel or equivalent size washed stone as a granular envelope, as follows:

Minor drainage collector swales shall possess a maximum channel length of 400 lineal feet, unless subsurface tile or swale invert treatment in the form of concrete paving is also provided. The required channel slope and invert treatment for minor drainage collector swales shall be as follows: grass lined swale if slope is 1% or greater and length is less than 400 feet; concrete paved channel or other acceptable treatment (such as a 2 ft. by 2 ft. trench filled with No. 8 washed gravel wrapped in fabric) if channel slope is between 0.3% and 0.5%, and/or length is greater than 400 feet; subsurface drainage tile if channel slope is between 0.5% and 1.0% and/or length is greater than 400 feet. The minimum channel slope shall be 0.3%.

For relatively large open channels and perennial streams, minimum channel slopes and the provision of subsurface drainage shall be approved on a case basis by the Plan Commission.

9.6 Establishment of New Regulated Drain

The Warsaw City Plan Commission may mandate that storm drains and detention basins in residential subdivisions become regulated drains to insure the proper maintenance of the system. If the Plan Commission mandates the establishment of a new Regulated Drain, each developer must provide the necessary information and meet the requirements of the 1965 Indiana Drainage Code, as amended, for the establishment of a new Regulated Drain. The Plan Commission shall determine the necessary easements for adequate maintenance of any new Regulated Drain.

9.7 Appurtenant Structures

The design of channels will provide all structures required for the proper functioning of the channel and the laterals thereto and travelways for operation and maintenance. Recessed inlets and structures needed for entry of surface and subsurface flow into channels without significant erosion or degradation shall be included in the design of channel improvements. The design is also to improve the necessary flood gates, water level control devices, and any other appurtenance affecting the functioning of the channels and the attainment of the purpose for which they are built.

The effect of channel improvements on existing culverts, bridges, buried cables, pipelines and inlet structures for surface and subsurface drainage on the channel being improved and laterals thereto shall be evaluated to determine the need for modification or replacement. Culverts and bridges which are modified or added as part of channel improvement projects shall meet reasonable standards for the type of structure, and shall have a minimum capacity equal to the design discharge or governmental agency design requirements, which ever is greater.

9.8 Disposition of Spoil

Spoil material resulting from clearing, grubbing and channel excavation shall be disposed in such a manner which will:

1) Minimize overbank wash.
2) Provide for the free flow of water between the channel and floodplain unless the valley routing and water surface profile are based on continuous dikes being installed.
3) Not hinder the development of travelways for maintenance.
4) Leave the right-of-way in the best condition feasible, consistent with the project purposes, for productive use by the owner.
5) Improve the aesthetic appearance of the site to the extent feasible.
6) Be approved by the IDNR or US Army Corps of Engineers (whichever is applicable) if deposited in the floodway.

9.9 Construction and Materials

A. Construction

Specifications shall be in keeping with the current standards of engineering practice and shall describe the requirements for proper installation of the project to achieve its intended purpose.

B. Materials

Materials acceptable for use as channel lining are:

1) Grass
2) Revetment Riprap
3) Concrete
4) Hand-laid Riprap
5) Precast Cement Concrete Riprap
6) Grouted Riprap
7) Gabions

Other lining materials shall receive specific approval of the Plan Commission or appointed Plan Director. Materials shall comply with the latest edition of the Indiana Department of Transportation's "Standard Specifications".

Section 10. Storm Water Detention

The following shall govern the design of any improvement with respect to the detention of storm water runoff.

10.1 Acceptable Detention Methods

The increased storm water runoff resulting form a proposed development should be detained on-site by the provisions of appropriate wet or dry bottom reservoirs, by storage on flat roofs, parking lots, streets, lawns, or other acceptable techniques. Measures which retard the rate of overland flow and the velocity in runoff channels shall also be used to control the runoff rate partially. Detention basins shall be sized to store excess flows from storms with a one hundred (100) year return period. Control devices shall limit the discharge to a rate no greater than that prescribed by the requirements in Section 3.

10.2 Design Storm

Design of storm water detention facilities shall be based on a return period of once in 100 years. The storage volume and outflow rate shall be sufficient to handle storm water runoff from a critical duration storm, as defined in Sections 10.5 and 10.6. Rainfall intensity-duration-frequency relationships shall be those given in Section 6.1.

10.3 Allowable Release Rate

The allowable release rate of storm water originating from a proposed development shall not exceed the amount specified in Section 3 and as described in Sections 10.5 and 10.6.

In the event the natural downstream channel or storm sewer system is inadequate to accommodate the release rate provided above, then the allowable release rate shall be reduced to that rate permitted by the capacity of the receiving downstream channel or storm sewer system, and additional detention as determined by the Plan Commission shall be required to store that portion of the runoff exceeding the capacity of the receiving sewers or waterways.

If more than one detention basin is involved in the development of the area upstream of the limiting restriction, the allowable release rate from any one detention basin shall be in direct proportion to the ratio of its drainage area to the drainage area of the entire watershed upstream of the restriction.

10.4 Drainage System Overflow Design

Drainage systems shall have adequate capacity to convey the storm water runoff from all upstream tributary areas through the development under consideration for a storm of 100 year design return period calculated on the basis of the upstream land in its present state of development. An allowance, equivalent to the reduction in flow rate provided, shall be made for upstream detention when such upstream detention and release rate have previously been approved by the Plan Commission or appointed Plan Director and evidence of its construction can be shown.

10.5 Determination of Storage Volume - Rational Method

For areas of two hundred (200) acres or less, the Rational Method may be used to determine the required volume of storm water storage. The following eleven step procedure may be used to determine the required volume of storage. Other design methods may also be used, subject to approval of the Plan Commission, as described in Section 10.6.

Procedure

(1) Determine total drainage area in acres "A".

(2) Determine composite runoff coefficient "Cu" based on existing land use (undeveloped).

(3) Determine time of concentration "tc" in minutes based on existing conditions

(4) Determine rainfall intensity "Iu" in inches per hour, based on time of concentration and Figure 1 or Equation 6.1.2 for a 10 year return period.

(5) Compute runoff based on existing land use (undeveloped), and 10 year return period:

$$Qu = Cu \times Iu \times A \qquad (10.5.1)$$

(6) Determine composite runoff coefficient "Cd" based on developed conditions and a one hundred (100) year return period.

(7) Determine the one hundred (100) year return period rainfall intensity "Id" for various storm durations "td" for the developed area using Figure 1 or Equation 6.1.2. Suggested storm durations are 5 min., 10 min., 15 min., 30 min., 1 hour, 2 hours continuing in 1 hour increments until a maximum storage is found.

(8) Determine developed inflow rates "Qd" for various storm durations "td"; measured in hours.

$$Qd = Cd \times Id \times A \qquad (10.5.2)$$

(9) Compute a storage rate "S" for various storm durations "td" up through the time of concentration of the developed area.

$$S = Qd - Qu \qquad (10.5.3)$$

(10) Compute required storage volume "V" in acre-feet for each storm duration "td". This assumes a triangular hydrograph of duration (2*td) hours with the peak flow of "S" at "td" hours.

$$V = (S \times td)/12 \qquad (10.5.4)$$

Note: The factor 1/12 in the above equation is used to convert cfs-hours to acre-ft.

(11) Select the largest storage volume computed in step 10 for detention basin design.

A worksheet for summarizing the calculations for this procedure can be found in Figure 3. An example of detention storage calculations using this worksheet can be found in Figure 4.

10.6 Determination of Storage Volume - Other Methods

Methods other than the Rational Method for determining runoff and routing of storm water may be used to determine the storage volume required to control storm water runoff. The procedures or methods used must receive the prior approval by the Plan Commission. The ILLUDAS, TR-20 and TR-55 models are approved by the Plan Commission for appropriate use in analysis of the runoff and routing of storm water. The use of these models or other approved procedures can be defined in a seven step procedure to determine the required storage volume of the detention basin.

Procedure

(1) Calibrate the hydrologic/hydraulic model that is to be used for prediction of runoff and routing of storm water.

(2) For various storm durations, perform steps three through six. Suggested storm durations are 5 min., 10 min., 15 min., 30 min., 1 hour, 2 hours continuing in 1 hour increments until a maximum storage is found in Step 6.

(3) Determine the ten (10) year, undeveloped peak flow. Denote this flow by Q_u^{10}.

(4) Determine the one hundred (100) year runoff hydrograph (H_d^{100}) for developed conditions.

(5) Determine the hydrograph that must be stored (H_s^{100}) by subtracting a flow up to Q_u^{10} from the hydrograph (H_d^{100}) found in step 4.

(6) Determine the volume of water (V_s) to be stored by calculating the area under the hydrograph H_s^{100}.

(7) The detention basin must be designed to store the largest volume (V_s) found for any storm duration analyzed in step 6.

Figure 4: Detention Storage Calculations

Using Rational Method

Project________________________________

Designer________________________________

1. Total Drainage Area (A)_________ (Acres)
2. Undeveloped Composite Runoff Coefficient (Cu)_________
3. Time of Concentration undeveloped condition (tc)_________minutes
4. Rainfall Intensity - 10 year return period (Iu)_________inches/hour
5. Undeveloped Runoff Rate (Qu = Cu x Iu x A)_________cfs
6. Developed Runoff Coefficient (Cd)_________

Storm Duration td (hrs)	Rainfall Intensity 100 year (7) Id (inches/hr)	Inflow Rate (8) Qd (Cd x Id x A) (cfs)	Outflow Rate (5) Qu (Cu x Iu x A) (cfs)	Storage Rate (9) S Qd - Qu (cfs)	Required Storage (10) V (S x td)/12 (acre-ft)

The maximum value computed for V is the required storage.

Figure 5: Example Detention Storage Calculations

Using Rational Method

Project__EXAMPLE______

Designer___________MSD____________________

1. Total Drainage Area (A)__23.4________ (Acres)
2. Undeveloped Composite Runoff Coefficient (Cu)___0.35_______
3. Time of Concentration undeveloped condition (tc)___23_______minutes
4. Rainfall Intensity - 10 year return period (Iu)__3.27________inches/hour
5. Undeveloped Runoff Rate (Qu = Cu x Iu x A)___26.78_______cfs
6. Developed Runoff Coefficient (Cd)___0.68_______

Storm Duration td (hrs)	Rainfall Intensity 100 year (7) Id (inches/hr)	Inflow Rate (8) Qd (Cd x Id x A) (cfs)	Outflow Rate (5) Qu (Cu x Iu x A) (cfs)	Storage Rate (9) S Qd - Qu (cfs)	Required Storage (10) V (S x td)/12 (acre-ft)	
0.17	7.51	119.45	26.78	92.67	1.29	
0.33	5.45	86.75	26.78	59.97	1.67	<==1.67 Acre-ft.
0.50	4.19	66.73	26.78	39.95	1.66	of storage Req'd
0.67	3.36	53.42	26.78	26.64	1.48	
0.83	2.77	44.04	26.78	17.26	1.20	
1.00	2.33	37.14	26.78	10.36	0.86	
1.50	1.54	24.46	26.78			
2.00	1.11	17.69	26.78			
3.00	0.68	10.83	26.78			
4.00	0.47	7.51	26.78			
5.00	0.35	5.60	26.78			
6.00	0.28	4.39	26.78			
7.00	0.22	3.56	26.78			
8.00	0.19	2.97	26.78			
9.00	0.16	2.52	26.78			
10.00	0.14	2.18	26.78			
11.00	0.12	1.91	26.78			
12.00	0.11	1.69	26.78			
13.00	0.09	1.51	26.78			
14.00	0.09	1.36	26.78			

The maximum value computed for V is the required storage.

10.7 Outflow Control Devices

The design of any retention facility requires the outflow be restricted to a maximum flow rate. This is usually accomplished with standard calibrated outflow device. The most common examples of calibrated outflow devices are orifices and weirs. Descriptions of these devices and the equations governing their operation are found below. Descriptions of other calibrated devices are beyond the scope of this document but can be found in most hydraulic reference texts.

A. Orifice

An orifice is a circular or rectangular opening of a prescribed shape and perimeter through which water flows. The flow rate is proportional to the height of water above the opening and the type of orifice. The equation for calculating orifice flow is given below.

$$Q = C_d A_o \sqrt{2gh_o} \tag{10.7.1}$$

Where: C_d = discharge coefficient
A_o = area of orifice (square feet)
g = acceleration due to gravity = 32.2 ft/sec^2
h_o = height above center of orifice (ft)

Table 8 - Discharge Coefficients C_d for Various Type of Orifices

Type	C_d
Square Edged	0.79 - 0.82
Round Edged	0.92 - 0.98
Sharp Edged	0.58 - 0.64
Projecting Sharp Edge	0.50

B. Weir

A weir is a depression or cutout in a wall or channel through which water flows. Many types of weirs exist, but this discussion will be limited to one type, a sharp-crested, rectangular weir. Descriptions of other types of weirs can be found in standard hydraulic reference texts. The equation governing flow through a rectangular weir is given below.

$$Q = \frac{2}{3} C_d \sqrt{2g} L h_w^{\frac{3}{2}} \tag{10.7.2}$$

Where: C_d = coefficient of discharge found by experiment or furnished by the manufacturer
h_w = height of water surface above weir opening (feet)
L = length of weir opening
g = acceleration due to gravity = 32.2 ft/sec^2

10.8 Alternative Method for Parcels Less than 2 Acres.

For parcels less than two acres, a complete retention design analysis using the Rational Method as described in Section 10.5 is not required. Instead, the designer may elect to store one inch of rainfall to be released at a maximum rate of 2 cubic feet per second. The volume required to store one inch of rainfall can be determined from the following equation.

$$V = 3630 \times A$$

Where: V = required storage volume in cubic feet
A = area of parcel in acres (1 acre = 43560 square feet)

The outflow control device must still be designed according to Section 10.7 to limit the outflow to 2 cfs. As an example, a basin with water 2.5 feet deep, would require a 6" diameter, squared edged orifice to limit the outflow to 2 cfs.

10.9 General Detention Basin Requirements

Basins shall be constructed to detain temporarily the storm water runoff which exceeds the maximum peak flow rate authorized by these requirements. The volume of storage provided in these basins, together with such storage as may be authorized in other on-site facilities shall be sufficient to control excess runoff from the one hundred (100) year storm.

The following design principles shall be observed:

(1) The maximum volume of water stored and subsequently released at the design release rate shall not result in a storage duration in excess of 48 hours unless additional storms occur within the period.

(2) The maximum planned depth of storm water stored (without a permanent pool) shall not exceed four feet.

(3) All storm water detention facilities shall be separated by not less that 75 feet from any building or structure to be occupied.

(4) All excavated excess spoil may be spread so as to provide for aesthetic and recreational features such as sliding hills, sports fields, etc. Slopes no steeper than 6 horizontal to 1 vertical for safety, erosion control, stability and ease of maintenance shall be permitted.

(5) Safety screens having a maximum opening of 4 inches shall be provided for any pipe or opening to prevent children or large animals from crawling into the structures.

(6) Danger signs shall be mounted at appropriate locations to warn of deep water, possible flooding conditions during storm periods and other dangers that exist. Fencing shall be provided if deemed necessary by the Plan Commission or the appointed Plan Director.

(7) Outlet control structures shall be designed to operate as simply as possible and shall require little or no maintenance and/or attention for proper operation. They shall limit discharges into existing or planned downstream channels or conduits so as not to exceed the predetermined maximum authorized peak flow rate.

(8) Emergency overflow facilities such as a weir or spillway shall be provided for the release of exceptional storm runoffs or in emergency conditions should the normal discharge devices become totally or partially inoperative. The overflow facility shall be of such design that its operation is automatic and does not require manual attention.

(9) Grass or other suitable vegetative cover shall be provided throughout the entire basin area. Grass should be cut regularly at approximately monthly intervals during the growing season or as required.

(10) Debris and trash removal and other necessary maintenance shall be performed on a regular basis to assure continued operation in conformance to design.

(11) A report shall be submitted to the Plan Commission describing (a) the proposed development; (b) the current land use conditions; (c) the method of hydraulic and hydrologic analysis used, including any assumptions or special conditions; (d) the results of the analysis; and (e) the recommended drainage control facilities. Hydraulic and hydrologic calculations, including input and output files, shall be included as appendices to the report.

10.10 Dry Bottom Basin Design Requirements

Detention basins which will not contain a permanent pool of water shall comply with the following requirements:

(1) Provisions shall be incorporated to facilitate complete interior drainage of dry bottom basins, to include the provisions of natural grades to outlet structures, longitudinal and transverse grades to perimeter drainage facilities, paved gutters, or the installation of subsurface drains. The minimum slope for the bottom of dry bottom basin shall be 1.0 percent. Unless designed as a swale according to Section 9.5.

(2) The detention basin shall, whenever possible, be designed to serve a secondary or multipurpose function. Recreational facilities, aesthetic qualities (open spaces) or other types of use shall be considered in planning the detention facility.

10.11 Wet Bottom Basin Design Requirements

Where part of a detention basin will contain a permanent pool of water, all the items required for detention storage shall apply except that the system of drains with a positive gravity outlet required to maintain a dry bottom basin will not be required. A controlled positive outlet will be required to maintain the design water level in the wet bottom basin and provide required detention storage above the design water level. However, the following additional conditions shall apply:

A. Basins designed with permanent pools or containing permanent ponds shall have a water area of at least one-half acre. If fish are to be maintained in the pond, a minimum depth of approximately 10 feet shall be maintained over at least 25 percent of the pond area. The remaining pond area shall have no extensive shallow areas, except as required by subsection C below.

B. In excavated ponds, the underwater side slopes in the pond shall be stable. In the case of valley storage, natural slopes may be considered to be stable.

C. A safety ledge four to six feet in width is required and must be installed in all ponds approximately 30 to 36 inches below the permanent water level. In addition, a similar maintenance ledge 12 to 18 inches above the permanent water line shall be provided. The slope between the two ledges shall be stable and of a material such as stone or riprap which will prevent erosion due to wave action.

D. A safety ramp exit from the pond is required in all cases and shall have a minimum width of 20 feet and exit slope to 6 horizontal to 1 vertical. The ramp shall be of a material that will prevent its deterioration due to vehicle use and/or wave action.

E. Periodic maintenance is required in ponds to control weed and larval growth. The pond shall also be designed to provide for the easy removal of sediment which will accumulate during periods of pond operation. A means of maintaining the designed water level of the pond during prolonged periods of dry weather is also required.

F. For emergency use, basin cleaning or shoreline maintenance, facilities shall be provided or plans prepared for auxiliary equipment to permit emptying and drainage.

G. Facilities to enhance and maintain pond water quality shall be provided, if required to meet applicable water quality standards. Design calculations to substantiate the effectiveness of these aeration facilities shall be submitted with final engineering plans. Agreements for the perpetual operation and maintenance of aeration facilities shall be prepared to the satisfaction of the Plan Commission or the Appointed Plan Director.

10.12 Roof Top Storage

Detention storage requirements may be met in total or in part by detention on flat roofs. Details of such designs are to be included in the building permit application and shall include the depth and volume of storage, details of outlet devices and down drains, and elevations of emergency overflow provisions.

10.13 Parking Lot Storage

Paved parking lots may be designed to provide temporary detention storage of storm waters on all or a portion of their surfaces. Outlets will be designed so as to empty the stored waters slowly. Depths of storage must be limited to a maximum depth of 7 inches so as to prevent damage to parked vehicles and so that access to parked vehicles is not impaired. Ponding should, in general, be confined to those positions of the parking lots farthest from the area served.

10.14 Facility Financial Responsibilities

The construction cost of storm water control systems and facilities as required by these requirements shall be accepted as part of the cost of land development. If general public use of the facility can be demonstrated, negotiations for public participation in the cost of such development may be considered.

10.15 Facility Maintenance Responsibility

Maintenance of detention/retention facilities during construction and thereafter, shall be the responsibility of the land developer/owner. Assignment of responsibility for maintaining facilities serving more than one lot or holding shall be documented by appropriate covenants to proceed by a public body, and shall be determined before the final drainage plans are approved.

Storm water detention and retention basins may be donated to the City or other unit of government designated by the City, for ownership and permanent maintenance providing:

A. The City or other governmental unit is willing to accept responsibility.

B. The facility has been designed and constructed according to all applicable provisions of these requirements.

C. All improvements have been constructed, approved and accepted by the City for the land area served by the drainage basin.

D. Retention ponds containing a permanent pool of water have all slopes between the riprap and high water line sodded and the remaining land area hydroseeded; are equipped with electrically driven aeration devices, if required to maintain proper aerobic conditions and sustain aquatic life; have a four-foot wide crushed limestone walkway at the high water line entirely around the body of water; provide suitable public access acceptable to the responsible governmental agency; and have the high water line not closer than 75 feet to any property line.

E. Dry detention ponds shall have all slopes, bottom of the basin and areas above the high water line hydroseeded; and shall have the high water line not closer that 50 feet to any development boundary.

10.16 Inspections

All public and privately owned detention storage facilities can be inspected by representatives of the City not less often than once every 2 years. If inspected, a certified inspection report covering physical conditions, available storage capacity and operational condition of key facility elements will be provided to the owner.

10.17 Corrective Measures

If deficiencies are found by the inspector, the owner of the detention/retention facility will be required to take the necessary measured to correct such deficiencies. If the owner fails to do so, the City will undertake the work and collect from the owner using lien rights, if necessary.

10.18 Joint Development of Control Systems

Storm water control systems may be planned and constructed jointly by two or more developers as long as compliance with these requirements is maintained.

10.19 Installation of Control Systems

Runoff and erosion control systems shall be installed as soon as possible during the course of site development. Detention/retention basins shall be designed with an additional (six) percent of available capacity to allow for sediment accumulation resulting from development and to permit the pond to function for reasonable periods between cleanings. Basins should be designed to collect sediment and debris in specific locations so that removal costs are kept to a minimum.

10.20 Detention Facilities in Floodplains

If detention storage is provided within a floodplain, only the net increase in storage volume above that which naturally existed on the floodplain shall be credited to the development. No credit will be granted for volumes below the elevation of the regulatory flood at the location unless compensatory storage is also provided.

10.21 Off-Site Drainage Provisions

When the allowable runoff is released in an area that is susceptible to flooding, the developer may be required to construct appropriate storm drains through such area to avert increased flood hazard caused by the concentration of allowable runoff at one point instead of the natural overland distribution. The requirement of off-site drains shall be at the discretion of the Plan Commission.

Section 11. Certifications Required

After completion of the project and before final approval and acceptance can be made, a professionally prepared and certified "As Built" set of plans shall be submitted to the Plan Commission for review. These plans shall include all pertinent data relevant to the completed storm drainage system and shall include:

(1) Pipe size and pipe material.

(2) Invert elevations.

(3) Top rim elevations.

(4) Lengths of all pipe structures.

(5) Data and calculations showing detention basin storage volume.

(6) Certified statement on plans stating the completed storm drainage system substantially complies with construction plans as approved by the Plan Commission.

All such submitted plans shall be reviewed for compliance within 30 days after submission to the Plan Director and County Surveyor. If notice of non-compliance is not given within 30 days of submission of the plans, the plans shall be construed as approved accepted.

Section 12. Changes in Plan

If the applicant wishes to amend the site plan in any way after the Drainage Plan has been approved by the Plan Commission, the applicant must inform the Plan Commission of the mandated or proposed change. If the Plan Commission or the appointed Plan Director determines the change in the building or site plan significantly changes the drainage as proposed under the currently approved Final Drainage Plan, additional information subject to the review and approval of the Plan Commission or appointed Plan Director may be required.

Section 13. Other Requirements

13.1 Sump Pumps

Sump pumps installed to receive and discharge groundwater or other storm waters shall be connected to the storm sewer where possible or discharged into a designated storm drainage channel. Sump pumps installed to receive and discharge floor drain flow or other sanitary sewage shall be connected to the sanitary sewers. A sump pump shall be used for one function only, either the discharge of storm waters or the discharge of sanitary sewage.

13.2 Down Spouts

All down spouts or roof drains shall discharge onto the ground or be connected to the storm sewer. No down spouts or roof drains shall be connected to the sanitary sewers.

13.3 Footing Drains

Footing drains shall be connected to storm sewers where possible or designated storm drainage channels. No footing drains or drainage tile shall be connected to the sanitary sewer.

13.4 Basement Floor Drains

Basement floor drains shall be connected to the sanitary sewers.

Section 14. Disclaimer of Liability

The degree of protection provided by these requirements is considered reasonable for regulatory purposes and is based on historical records, engineering and scientific methods of study. Larger storms may occur or storm water runoff depths may be increased by man-made or natural causes. This document does not imply that land uses permitted will be free from storm water damage. These requirements shall not create liability on the part of the City of Warsaw or any officer or employee thereof for any damage which may result from reliance on these requirements or on any administrative decision lawfully made thereunder.

Section 15. References

Burke, Christopher B., and Thomas T. Burke, "Stormwater Drainage Manual", Purdue Research Foundation, West Lafayette, Indiana, July 1994.

Ordinance 1993-7, Marshall County, Indiana, Storm Drainage and Sediment Control Ordinance, October 1993.

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